

# The LHCb Upgrade

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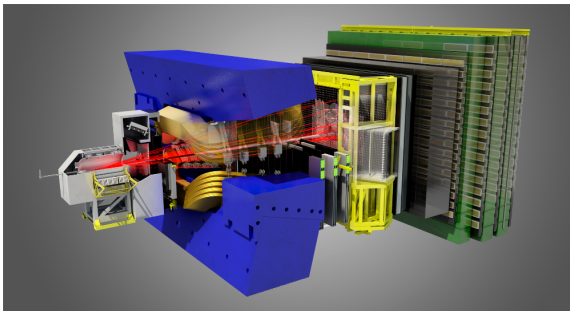
on behalf of the LHCb Collaboration

August 1, 2017



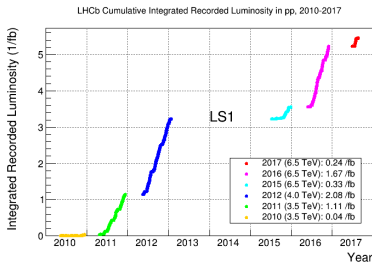
# The LHCb experiment

- Single arm spectrometer focused on physics of  $b$  and  $c$  hadrons
- Also general purpose forward detector
- Strengths are precise tracking and particle identification



# Luminosity beyond Run 2

- Currently over  $5 \text{ fb}^{-1}$
- $\mathcal{L} = 4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- Usually one  $p-p$  interaction



- Goal – collect  $50 \text{ fb}^{-1}$  in Runs III and IV
- Higher luminosity
- $\mathcal{L} = 2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- More interactions per crossing

# Limitations

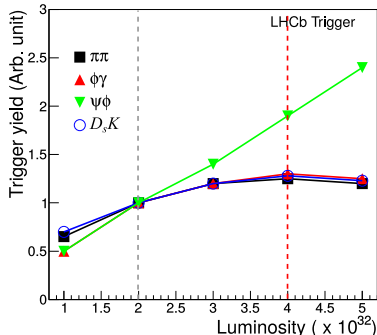
- Hardware trigger limits exploitation of that data

  - Rate of 1.1 MHz

- Sub-detectors will struggle

  - Radiation damage

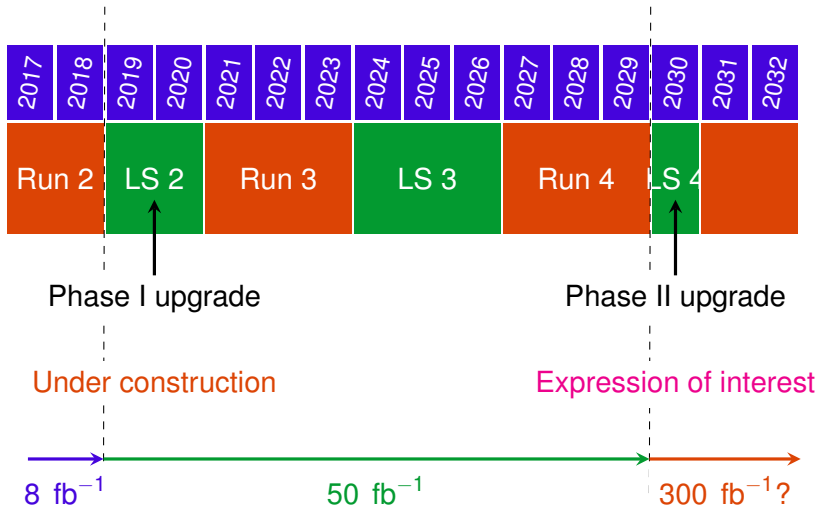
  - Increased occupancy



Some states don't benefit from increasing luminosity



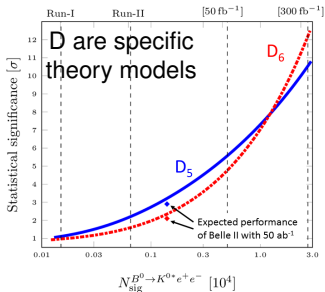
# Upgrades



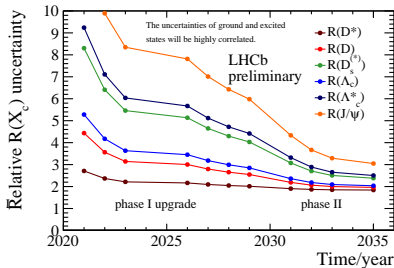
# Physics case

## Two examples

- Key measurements improve even through Phase II
- New channels open up



Discovery potential for lepton non-universality in  $K^{*0} \ell \ell$



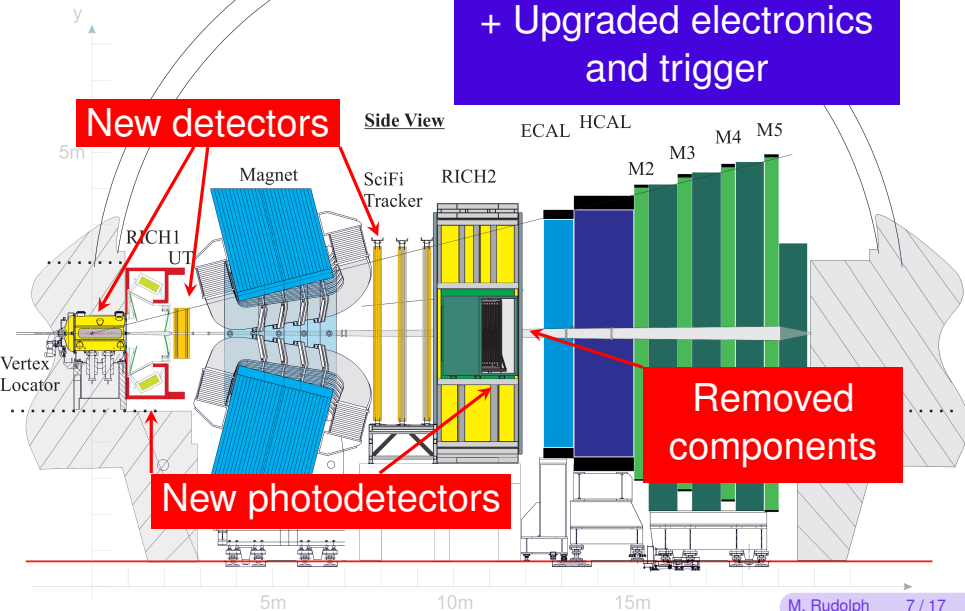
Uncertainty on  $\tau/\mu$  ratio in semileptonic decays

# The big picture

+ Upgraded electronics  
and trigger

New detectors

Side View



# Trigger and readout

Linchpin of the upgrade

- Remove hardware trigger
- Software only trigger
- Online calibration
- Higher rate to storage

## LHCb Upgrade Trigger Diagram

**30 MHz inelastic event rate  
(full rate event building)**

### Software High Level Trigger

Full event reconstruction, inclusive and exclusive kinematic/geometric selections

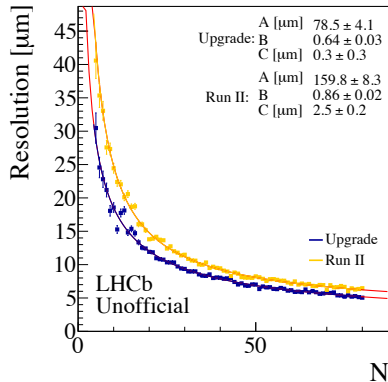
Buffer events to disk, perform online detector calibration and alignment

Add offline precision particle identification and track quality information to selections  
Output full event information for inclusive triggers, trigger candidates and related primary vertices for exclusive triggers

**2-5 GB/s to storage**

# Trigger performance

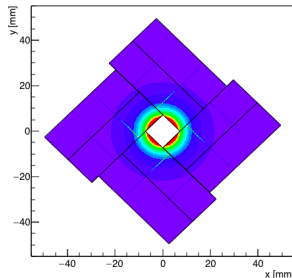
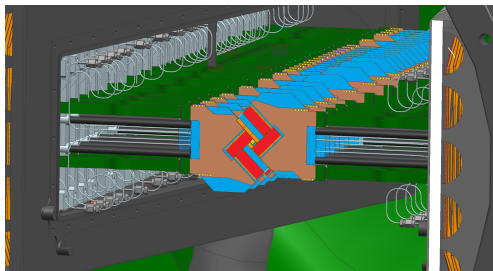
- Essential that “fast” reconstruction step also performant
- Tracking efficiency
- Low “ghost” rate of 5.6% in fast stage
- Vertex resolution also good



Primary vertex resolution

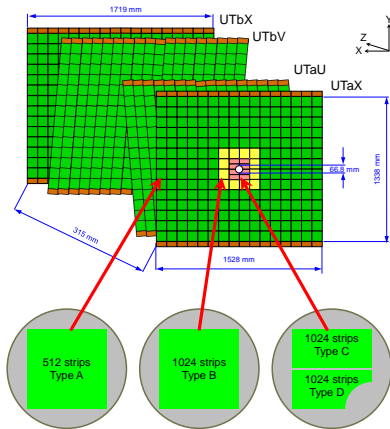
# Vertex Locator (VELO)

- Closest to collision point
- New silicon pixel detector
- Sensors start 5.1 mm from beam



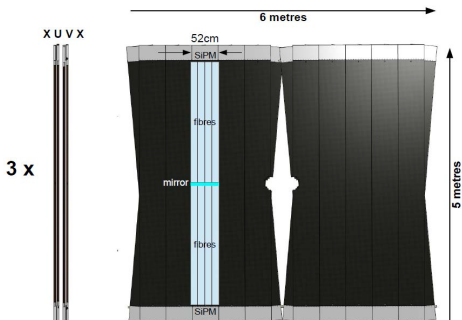
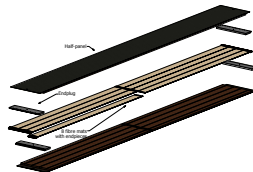
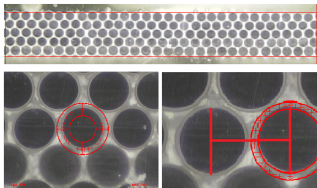
# Upstream Tracker

- 4 plane silicon strip tracker
- No acceptance gaps
- Get close to beam with circular cutout
- Fine segmentation in inner region



# SciFi

- Scintillating Fiber Tracker
- 250  $\mu\text{m}$  fibers
- Almost 340  $\text{m}^2$  area

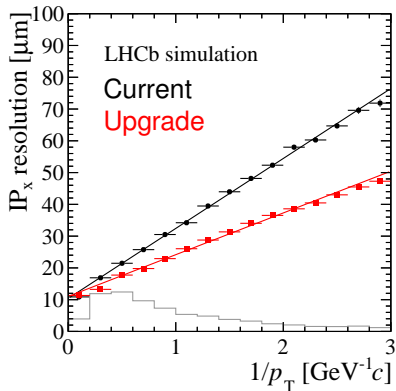
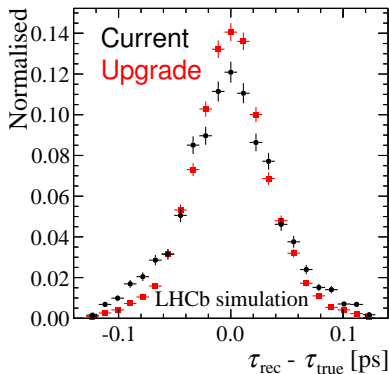




# Velo performance

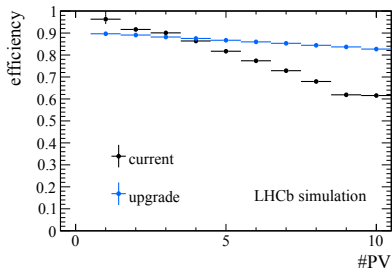
## Critical for

- Vertex finding
- Lifetime resolution
- Impact parameter resolution

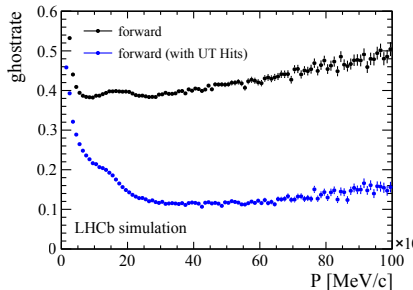


# Tracking performance

Maintain efficiency with more pile-up



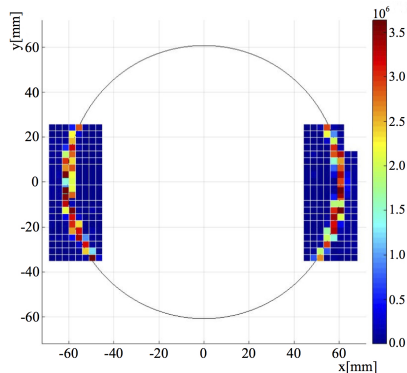
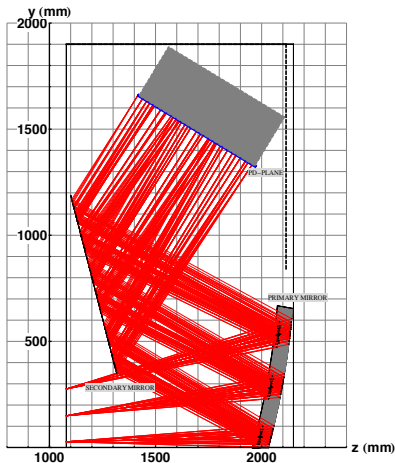
Remove “ghost” tracks



# RICH upgrades

Ring Imaging Cherenkov detectors

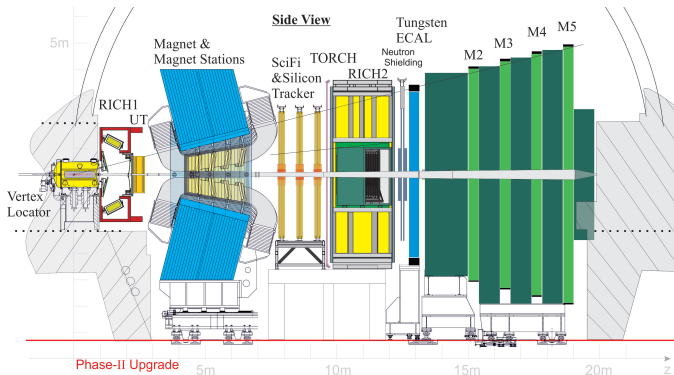
- Improved resolution
  - Adjust optics of RICH1 for occupancy
  - New 64 ch. Multi-Anode PMTs



# Phase 2 upgrades

Beyond Run 4

- Increased occupancy and radiation a major challenge
- Major additions under consideration:
  - Tracking chambers inside magnet
  - Timing upgrades and TORCH downstream time-of-flight
  - New EM calorimeter



# Conclusions

- LHCb phase I upgrades to leverage increased luminosity
  - Set to install during LS2 2019-2020
- Full software trigger
  - Readout full rate
  - Online calibration
- New tracking detectors to improve performance even with increasing pile-up
- Improvements to RICH resolution
- Enables data taking to greatly extend sensitivity to new physics